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# Evaluation of the TRIMAX 280 System

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Evaluations of the TRIMAX 280 were conducted to determine its suitability for use by Marine Corps personnel in support of forward deployed units; specifically, MOS 7051, Aircraft Rescue and Firefighting Specialists with the primary mission of rescue and fire suppression during aviation related incidents. This test series evaluated the TRIMAX 280 for fire fighting operational adequacy and overall system performance using fixed orifice and variable stream nozzles with compressed air foam. A series of five JP-8 pool fires of 2500-ft$^2$, three JP-8 3500-ft$^2$pool fires with F100 engine nacelle mockup, and one JP-8 700-ft$^2$ with F100 engine nacelle mockup were used to evaluate the 90% control and full extinguishment times. System operation was evaluated by conducting tests for throw distance, agent duration, agent stream decay, agent flow rate, expansion ratio and 25% drainage time. The TRIMAX 280 controlled and extinguished all but one of nine fires. The first 3500-ft$^2$ fire attempted was not extinguished prior to agent depletion. System evaluation showed no performance inadequacies.

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## Abstract

The evaluation of the TRIMAX 280 was conducted to determine its suitability for use by Marine Corps personnel in support of forward deployed units; specifically, MOS 7051, Aircraft Rescue and Firefighting Specialists with the primary mission of rescue and fire suppression during aviation related incidents. This test series evaluated the TRIMAX 280 for fire fighting operational adequacy and overall system performance using fixed orifice and variable stream nozzles with compressed air foam. A series of five JP-8 pool fires of 2500-ft$^2$, three JP-8 3500-ft$^2$pool fires with F100 engine nacelle mockup and one JP-8 700-ft$^2$ with F100 engine nacelle mockup were used to evaluate the 90% control and full extinguishment times. System operation was evaluated by conducting tests for throw distance, agent duration, agent stream decay, agent flow rate, expansion ratio and 25% drainage time. The TRIMAX 280 controlled and extinguished all but one of nine fires. The first 3500-ft$^2$ fire attempted was not extinguished prior to agent depletion. System evaluation showed no performance inadequacies.

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# I. Introduction

## A. *Background*

During the past 18 months, numerous tests were conducted with the Compressed Air Foam System-Mobile (CAFS-M), and although the results have been accepted by the Bulk Fuel and Ammo Supply Point communities relative to pool fires, the CAFS-M does not meet the special requirements of the Aircraft Rescue Fire Fighting (ARFF) community. The knockdown capability necessary for effective aircrew and passenger rescue is a critical issue. A Market Survey of GSA listed fire fighting equipment suitable in form, fit, function, cost and availability was conducted to find what, at the onset, might be considered as an interim solution for the ARFF deficiency. The TRIMAX 280 was identified as a suitable evaluation candidate for this interim solution.

## B. *Purpose*

The evaluation of the TRIMAX 280 was conducted to determine its suitability for use by Marine Corps personnel in support of forward deployed units; specifically, MOS 7051, Aircraft Rescue and Fire Fighting Specialists with the primary mission of rescue and fire suppression during aviation related incidents.

## C. *Scope*

The TRIMAX 280 was tested to evaluate the following:

- Operational adequacy for firefighting including:
    - 2500 $ft^2$ static pool fires
    - 3500 $ft^2$ static pool fires with F100 engine nacelle mockup
    - 700 $ft^2$ static pool fire with F100 engine nacelle mockup
- Overall system performance including:
    - Throw distance of foam and foam with dry chemical
    - Flow rate of foam and dry chemical
    - Application duration of foam and dry chemical
    - Agent decay over application time
    - Foam expansion ratio
    - Drainage time, 25%

# II. Results and Conclusions

## A. *Fire Scenarios*

### 1. 2500 Sq. Ft. Fires

The TRIMAX 280 exceeded the ARFF requirements for control (<60 seconds) and extinguishment (<120 seconds) of a 2500-ft$^2$ hydrocarbon static pool fire. Four of five fires reported control times less than 60 seconds and extinguishment times less than 69 seconds. One fire, test 2500-1, had a 90% control time of 81.06 and full extinguishment at 99.59 seconds. This fire was reignited during the test from a fire outside of the test parameter ring resulting in a higher 90% control time.

These fires were fought using the Williams variable stream Hydrochem™ nozzle, except for test P-2, which utilized the Williams fixed orifice Hydrochem™ Compressed Air Foam (CAF) nozzle.

### 2. 3500 Sq. Ft. Fires

One-half of the available fire pit area was utilized to create three pool fires with an F100 engine nacelle placed under the wing of the aircraft mockup. Using the variable stream nozzle on the first attempt, the fire was not extinguished before running out of agent. Using the same type nozzle, the second fire was extinguished just prior to agent depletion.

The third fire was completed without any incident using the CAF nozzle. The 90% control time was 109.98 seconds and full extinguishment time was 127.18 seconds. Agent was still available at time of extinguishment.

### 3. 700 Sq. Ft. Fire

One test was performed with the 700-ft$^2$ pool fire with F100 engine nacelle mockup using the variable stream nozzle. While maximum control and extinguishment times were not established for this test, the TRIMAX 280 was able to control and extinguish the fire within the capacity of the system at 22.77 and 32.36 seconds, respectively.

## B. *System Evaluation*

Both TRIMAX 280 systems were evaluated for operational parameters. They were referred to by the serial numbers, 520-04 and 520-06. With the exception of the foam expansion ratio and drainage tests, all system evaluations were performed with the variable stream nozzle only, per instructions from Chief Warrant Officer (CWO) 5 Paul Bungcayao of Aviation Supply Logistics (ASL).

### 1. Throw distance of foam and foam with dry chemical

The test showed the TRIMAX 280 system could maintain a maximum throw range of just over 50 feet with foam alone and over 62 feet with foam and dry chemical together, or beyond the 50-foot minimum distance criteria.

System 520-06 exceeded minimum requirements of a 50-foot throw distance in straight stream mode by 12 feet. The TRIMAX 280 has sufficient throw distance to provide adequate standoff distance for the firefighter, minimizing radiant heat exposure.

### 2. Application duration of foam and dry chemical

The TRIMAX 280 application duration time for foam was 2:51:75. The application duration time for the dry chemical was 1:11:03.

### 3. Agent stream decay over application time

Evaluation of the video from both systems showed that the agent stream remained steady in flow rate and throw distance. The video showed that the firefighter could expect over 2½ minutes of consistent foam agent application.

### 4. Flow rate of foam and dry chemical

National Fire Protection Agency (NFPA) 414 for ARFF vehicle flow rate tolerances states that the flow rate must be +10 percent/-0 percent of the manufacturers specifications. No manufacturer specification for the TRIMAX 280 were provided for verification.

The foam flow rate was 24.4 gallons per minute (gpm) and the dry chemical flow rate was 6.1 pounds per second (pps). The flow rates of each agent can be adjusted by increasing or decreasing the pressure regulators for each agent tank.

### 5. Foam expansion ratio and 25% foam drainage time

A total of ten expansion ratio and two drainage tests were performed with the TRIMAX 280. Foam expansion ratio tests conducted on the air-aspirated foam, with either the CAF nozzle or variable stream nozzle, demonstrated that the system exceeded minimum requirements, as stated in NFPA 412. System 520-04 produced foam with a 25% drainage time of 10.95-10.96 minutes using the variable stream nozzle in air-injection mode (Table 13), which exceeded NFPA minimum requirements. Four foam expansion ratio tests were conducted with the variable nozzle and no injection air (two tests with each system), which produced foam that was below the NFPA minimum expansion ratio requirements (2.39-2.62:1).

# I. Introduction

## A. *Background*

On June 10, 1998 the Assistant Commandant of the Marine Corps approved the Operational Requirements Document (ORD) for the Compressed Air Foam System - Mobile (CAFS-M) to replace the M1028FF Twin Agent Unit (TAU)[1]. The TAU has developed reliability problems in several major subsystems that degrade readiness and its host vehicle (M1008 Commercial Utility Cargo Vehicle (CUCV) is no longer in the inventory. The CAFS-M replacement must provide initial response fire protection capabilities to the Marine Air Ground Task-Force (MAGTF) Air Combat Element (ACE) and Combat Service Support Element (CSSE). CAFS requirement capabilities and Key Performance Parameters (KPPs) are outlined in the ORD.

During the past 18 months numerous tests were conducted with the Compressed Air Foam System-Mobile (CAFS-M), and although the results have been accepted by the Bulk Fuel and Ammo Supply Point communities relative to pool fires, the CAFS-Ms does not meet the special requirements of the Aircraft Rescue Fire Fighter (ARFF) community. The knockdown capability necessary for effective aircrew and passenger rescue is a critical issue. A Market Survey of GSA listed fire-fighting equipment suitable in form, fit, function, cost and availability was conducted to find what, at the onset, might be considered as an interim solution for the ARFF deficiency. The TRIMAX 280 was identified as a suitable evaluation candidate for this interim solution.

## B. *Purpose*

The evaluation of the TRIMAX 280 was conducted to determine its suitability for use by Marine Corps personnel in support of forward deployed units; specifically, MOS 7051, Aircraft Rescue and Fire Fighting Specialists with the primary mission of rescue and fire suppression during aviation related incidents.

## C. *Scope*

The TRIMAX 280 was tested to evaluate the following[2]:

- Operational adequacy for firefighting including:
    - 2500 $ft^2$ static pool fires
    - 3500 $ft^2$ static pool fires with F100 engine nacelle mockup and aircraft mockup
    - 700 $ft^2$ static pool fire with F100 engine nacelle mockup

**Note: The F100 engine nacelle mockup allows evaluation of three-dimensional (3-D) running fuel fires and the static pool allows evaluation of the two-dimensional (2-D) pool fire, which is often a result of the running fuel fire.**

- Overall system performance including:
    - Throw distance of foam and foam with dry chemical
    - Flow rate of foam and dry chemical
    - Foam to dry chemical ratio
    - Application duration of foam and dry chemical
    - Agent decay of application time
    - Foam expansion ratio
    - Drainage time, 25%

## II. Methods, Assumptions and Procedures

All testing was conducted at the Live Fire Test Facility, Silver Flag Exercise Site, Tyndall AFB, FL in facilities controlled by the Air Force Research Laboratory. Facilities included an environmentally controlled 100-ft diameter hydrocarbon fire pit facility with aircraft mockup (Figure 1).

**Figure 1. Air Force Research Laboratory Full-Scale Fire Test Facility, Tyndall AFB, FL.**

### A. *Test Vehicles*

Marine Corps System Command (MARCORSYSCOM) delivered two test units to Tyndall AFB, FL for the duration of testing. Examination of the TRIMAX 280s by a TRIMAX representative determined both units were in proper working order at the time of arrival. Assuming no mechanical problems during testing, AFRL and MARCORSYSCOM agreed that alternating use of the TRIMAX 280 systems

would allow for efficient use of available testing time. Chief Warrant Officer (CWO) 5 Paul Bungcayao of Aviation Supply Logistics (ASL) changed the Williams fixed orifice Compressed Air Foam (CAF) Hydrochem™ nozzle to the Williams variable stream Hydrochem™ nozzle because that is what the ARFF community train with and use. Both units were used for system evaluation (i.e. throw distance, expansion ratio, etc). The systems were numbered 520-04 and 520-06.

## B. *Firefighter Qualifications*

All fire fighting was performed by Marine Corps qualified aircraft rescue firefighters using ARFF firefighting Directives. These firefighters were representative of firefighters that would be using the system on a regular basis.

## C. *Fire Scenarios*

### 1. 2500 Sq. Ft. Practice Fires

#### a. Description

- A 2500 sq. ft. area was constructed in half of the Large Scale Fire Evaluation Facility (Fire Pit) using 6 inch X 8 foot strips of steel to section off the front and rear pit areas. The steel strips were held in place by course aggregate. The Fire Pit was filled with 500 gallons of JP-8 jet fuel (approximately 0.2 gal/ft$^2$) on top of a 1-inch layer of water. The TRIMAX 280 was fully serviced prior to each fire and discharged for approximately 5 seconds prior to lighting the fire as a pre-fire system check. A propane torch was used to ignite the JP-8 and a pre-burn of 45 seconds was conducted to assure full involvement of the fuel in the fire area. The firefighter was given a ten second countdown, at which time, an aggressive attack mode was used to extinguish the fire. An aggressive attack mode was characterized by quick sweeps with the nozzle in close proximity to the fire and was the typical fire attack technique for Marine firefighters. Two practice fires were performed to the satisfaction of the Air Force Research Laboratory (AFRL) Test Director before proceeding with the three 2500 ft$^2$ pool fires. The first practice fire was performed with the variable stream nozzle and the second was performed with the CAF nozzle.

**Note: Time to extinguishment was based on extinguishment of the pool fire on within the ring. Fire remaining outside of the ring was not considered part of the square footage of the fire or extinguishment time.**

#### b. Criteria for Success

Success was defined as completion of the practice tests to the satisfaction of the AFRL Test Director. The two 2500 ft$^2$ practice fires allowed the firefighters to become familiar with the test equipment while allowing for an equipment check of

the TRIMAX 280 unit, hoses and nozzles. After completing one test with each nozzle, Chief Warrant Officer (CWO) 5 Paul Bungcayao of Aviation Supply Logistics (ASL) made the decision to use the variable nozzle for the remainder of the testing because that is what the ARFF community is trained on and uses presently.

## 2. 2500 Sq. Ft. Fires

### a. Description

The 2500 $ft^2$ static pool fires were fought with the variable stream nozzle. All three fires were fully extinguished. The Fire Pit was filled with 750 gallons of JP-8 jet fuel (approximately 0.3 gal/$ft^2$) on top of a 3-inch layer of water. The TRIMAX 280s were fully serviced prior to each fire and discharged for approximately 5 seconds prior to lighting the fire. A propane torch was used to ignite the JP-8 and a pre-burn of 60 seconds was conducted to assure full involvement of the fuel in the fire area. The firefighter was given a ten second countdown, at which time an aggressive attack mode was used to extinguish the fire. Time to extinguishment was based on extinguishment of the pool fire within the ring. Any fire extinguished outside the ring was not included in the final time.

### b. Criteria for Success

The 2500 $ft^2$ pool fire was conducted to provide MARCORSYSCOM with an estimation of current system performance for comparison with previous test data; in particular, the Compressed Air Foam System-Mobile (CAFS-M). Based on Aircraft Rescue and Firefighting (ARFF) maximum allowable standards, the test was considered a success if the fire was controlled within 60 seconds and extinguished within 120 seconds. Control time was defined as the time required to extinguish 90% of the fire area whereas extinguishment time was defined as the time required to extinguish 100% of the fire area.

## 3. 3500 Sq. Ft. Fires

### a. Description

After completion of the 2500-$ft^2$ fires, 3500-$ft^2$ pit pool fires with F100 engine nacelle mockup were conducted. The F100 engine nacelle mockup was used to represent a three-dimensional (3-D) running fuel fire and was effective for evaluating the TRIMAX 280 against a 3-D fire scenario (Figures 2&3). The steel ring from the previous fire was removed so that the half of the 100-ft diameter pit area could be utilized. 1050 gallons (0.3 gal/$ft^2$) of JP-8 jet fuel were added to the fire pit to assure complete fire coverage. A pre-burn time of 60 seconds assured full involvement of the fuel in the fire area. The firefighter used the same aggressive, close proximity attack techniques as in the previous fires. Time to extinguishment was based on the extinguishment of the pool and the F100 engine nacelle fire. Any fire extinguished on the banks of the fire pit area was not included in the final time. Only full extinguishment times were recorded as estimating 90% control with the F100 3-D running fuel fire was impossible. The

variable steam nozzle was used for tests 3500-1 and 3500-2. The CAF nozzle was used for test 3500-3.

**Figure 2. F100 Engine Nacelle Mockup, Side View**

**Figure 3. F100 Engine Nacelle Mockup, Front View**

### b. Criteria for Success

This test series did not correlate to any existing NFPA requirements; therefore, no maximum control or extinguishment times were established. The test was conducted to provide MARCORSYSCOM with an estimation of overall system performance, effectiveness and limitations.

## 4. 700 Sq. Ft. Fire

### a. Description

After completion of the 2500-ft$^2$ and 3500-ft$^2$ fires, a 700-ft$^2$ pool fire with F100 engine nacelle mockup was conducted. A 30-ft diameter steel ring was constructed around the F100 engine nacelle. 65 gallons of JP-8 jet fuel were added to the fire pit just prior to lighting to assure a complete fire coverage area. A pre-burn time of 45 seconds assured full involvement of the fuel in the fire area. The firefighter extinguished the fire using the same aggressive, close proximity attack techniques as in the two previous sized fires. Time to extinguishment was based on the extinguishment of the fire on the pool of water and the F100 engine nacelle. Any fire extinguished on the banks of the Fire Pit area was not included in the final time. Only full extinguishment times were recorded as estimating 90% control with the F100 3-D running fuel fire was impossible.

### b. Criteria for Success

This test series did not correlate to any existing NFPA requirements; therefore, no maximum control or extinguishment times were established. The test was conducted to provide MARCORSYSCOM with an estimation of overall system performance, effectiveness and limitations.

## D. *System Evaluation*

Two separate systems were evaluated for operational parameters, referred to by the serial numbers, 520-04 and 520-06. Each of the two TRIMAX 280 systems was fully serviced prior to agent discharge. Agent application duration, agent stream decay and agent discharge flow rate were performed for informational purposes only (as no minimum guidelines or standards were established prior to testing). Maximum throw distance was evaluated against an existing Marine ORD. Expansion ratio and drainage time were evaluated against NFPA requirements. Per instructions from CWO 5 Bungcayao, all system evaluations were performed with the variable stream nozzle only, with the exception of the foam expansion ratio and drainage tests, which used both nozzle configurations.

### 1. Maximum Throw Distance

Test personnel were situated around the fire pit such that the agent would be discharged in the direction of the prevailing wind. CWO 5 Paul Bungcayao of ASL amended the test plan and decided to only test the variable stream nozzle for maximum throw distance after he determined that the CAF nozzle would not be used by the Marines with the TRIMAX 280 system.

#### a. O° (level)

Test personnel held the nozzle at waist height, parallel to the ground while the agents were discharged. Cones were used to mark the maximum throw distance at this angle of the foam and the foam plus the dry chemical at 0° (level).

#### b. Maximum

After the maximum throw distance at O° was determined, test personnel raised the nozzle to the angle that would maximize the throw distance (approximately 20°). Separate cones were used to mark the maximum throw distance at this angle for the foam and the foam plus the dry chemical.

At the completion of the agent discharge, a tape measure was used to determine the exact throw distance for each elevation.

#### c. Criteria for Success

This test series did not correlate to any NFPA requirement. However, a Marine ORD mandated a continuous foam spray of 20 feet (threshold) and a straight foam stream of 50 feet (threshold). Evaluation of throw distance only included the variable stream nozzle in a straight stream mode.

### 2. Agent Application Duration

Foam agent application duration was measured by timing the agent discharging starting with a full premixed foam/water tank and discharging until empty.

Dry chemical agent application duration was measured by timing the agent discharging starting with a full dry chemical tank and discharging until empty.

#### Criteria for Success

This test series did not correlate to any NFPA requirement and results were given for informational purposes only.

### 3. Agent Stream Decay over Application Time

Agent decay was evaluated by reviewing video of the agent discharge testing. Agent discharge decay is defined as the point at which the agent stream begins to lose throw distance.

#### Criteria for Success

This test series did not correlate to any NFPA requirement and results were given for informational purposes only.

### 4. Agent Discharge Flow Rate

The agent discharge flow rate was determined by dividing the total amount of agent discharged by the time the agent took to completely discharge.

#### Criteria for Success

NFPA 414 requires the measured flow rate to equal the specified flow rate within a tolerance of +10 percent/-0 percent.[3] The manufacturer did not provide specifications for flow rate as a comparison. Also, flow rate can be adjusted on this system by increasing or decreasing the pressure regulators.

### 5. Foam Expansion Ratio

Foam expansion ratio was measured by the methods specified in the National Fire Protection Agency (NFPA) 412, Standard for Evaluating Aircraft Rescue and Fire-Fighting Foam Equipment[4] (See Appendix for complete description of method). The CAF nozzle was tested with the air injection set at 50%. The variable stream nozzle was tested without injection air (standard operating mode) and with 50% injection air (enhanced operating mode) to determine any differences in foam quality when using injection air with the variable stream nozzle.

#### Criteria for Success

NFPA 412 requires a minimum expansion ratio of 5:1 for air-aspirated AFFF and 3:1 for non-air-aspirated AFFF. No requirements exist for foam expansion ratio when used in combination with dry chemical.

### 6. Foam Drainage Time, 25%

Foam drainage time, 25% was measured by the methods specified in the National Fire Protection Agency (NFPA) 412, Standard for Evaluating Aircraft Rescue and Fire-Fighting Foam Equipment[4] (See Appendix for complete description of method).

### Criteria for Success

NFPA 412 requires a minimum 25% foam drainage of three minutes for air-aspirated and one minute for non-air-aspirated AFFF using Test Method A.

# III. Results and Discussion

## A. *Fire Scenarios*

Nine fires of three different sizes were conducted over a three-day period. Weather conditions remained constant during the three-day test interval with temperatures ranging between 74-82°F and winds generally ranging from 7-12 mph, even early in the morning. Wind conditions during the week of testing were above optimal (1-4 mph); therefore, adjustments to test protocol were necessary. Fuel pouring was normally accomplished simultaneously with test setup (i.e. donning gear, positioning backup vehicles, staging video cameras, etc) to optimize test time. To assure total coverage of the pool area, the fuel was poured after all pre-staging was complete, then immediately ignited before the wind could push the fuel to one side of the pool. The pool areas for all nine fires were 100% involved.

### Time Data Sources

Extinguishment times were collected from three different sources:

- During each fire: Multiple stopwatches were used during each event. Representatives from MARCORSYSCOM, TRIMAX and AFRL provided time inputs.
- From camera 1.
- From camera 2.

Differences in 90% control times and full extinguishment times can be attributed to position relative to the fire and individual ability to estimate when the fire was actually extinguished (especially for the 90% control times). An average of all time sources was considered the official times for both 90% and full extinguishment.

### 1. 2500 Sq. Ft. Fires

#### a. P-1

The first 2500-ft$^2$ fire was used as a practice test to assure the equipment, unit 520-06, was operating correctly and to familiarize the firefighters with the system. This test was performed using the variable stream nozzle. During the test the firefighters were unable to discharge the dry chemical. A system check concluded that the hose was clogged. Clearing the hose of clogs restored dry chemical agent flow and the vehicle was reserviced for another fire. The 90% control and full extinguishment times were 42.81 and 60.46 seconds, respectively (Table 1).

**Table 1. Extinguishment Times (seconds) and Parameters for Test P-1.**

| | | | Times (Seconds) | | |
|---|---|---|---|---|---|
| **Test Number** | **Camera View** | **Test Times Taken** | **Pre-Burn** | **90% Control** | **Full Extinguishment** |
| **P-1** | | | 45.00 | | 58.47 |
| | | | | | 65.00 |
| Fuel Load | | | | | NA |
| 500 | East | From Camera 1 | 45.00 | 43.76 | 59.09 |
| | North | From Camera 2 | | 41.86 | 59.28 |
| | | **Average** | | **42.81** | **60.46** |

#### b. P-2

Test P-2, completed without incident, was also used as a practice test to assure the equipment, unit 520-04, was operating correctly and to familiarize the firefighters with the system. This test was performed using the CAF Hydrochem™ nozzle. No problems were encountered with the system and the control time was within ARFF requirements at 40.05 seconds (Table 2), or almost 20 seconds before the 60 second allowance. Full extinguishment was slightly over one minute at 63.36 seconds.

**Table 2. Extinguishment Times (seconds) and Parameters for Test P-2.**

| | | | Times (Seconds) | | |
|---|---|---|---|---|---|
| **Test Number** | **Camera View** | **Test Times Taken** | **Pre-Burn** | **90% Control** | **Full Extinguishment** |
| **P-2** | | | 45.00 | | 67.88 |
| | | | | | 62.00 |
| Fuel Load | | | | | NA |
| 250 | East | From Camera 1 | 44.79 | 41.17 | 61.10 |
| | South | From Camera 2 | | 38.92 | 62.44 |
| | | **Average** | | **40.05** | 63.36 |

#### c. 2500-1

Test 2500-1 was completed without any incident. The variable stream nozzle was used on unit 520-06. No problems were encountered with the system; however, the fire appeared to burn back from outside the ring resulting in a

longer control and extinguishment time. While the 90% control time (81.06 seconds) exceeded the 60 second requirement, the full extinguishment time (99.59 seconds) was within 120 second maximum (Table 3).

**Table 3. Extinguishment Times (seconds) and Parameters for Test 2500-1.**

| | | | Times (Seconds) | | |
|---|---|---|---|---|---|
| **Test Number** | **Camera View** | **Test Times Taken** | **Pre-Burn** | **90% Control** | **Full Extinguishment** |
| **2500-1** | | | 60.00 | | 71.06 |
| | | | | | 69.50 |
| | | | | | 115.02 |
| Fuel Load | | | | | 114.37 |
| 300 | East | From Camera 1 | 62.50 | 86.73 | 113.10 |
| | North | From Camera 2 | | 75.39 | 114.50 |
| | | **Average** | | **81.06** | **99.59** |

### d. 2500-2

Test 2500-2 was completed without any incident. The variable stream nozzle was used on unit 520-04. The control and full extinguishment time for this fire were within the 60-second control and 120-second extinguishment requirements at 56.29 seconds and 69.10 seconds, respectively (Table 4).

**Table 4. Extinguishment Times (seconds) and Parameters for Test 2500-2.**

| | | | Times (Seconds) | | |
|---|---|---|---|---|---|
| **Test Number** | **Camera View** | **Test Times Taken** | **Pre-Burn** | **90% Control** | **Full Extinguishment** |
| **2500-2** | | | 60.00 | | 71.00 |
| | | | | | 72.27 |
| | | | | | 69.04 |
| Fuel Load | | | | | 67.59 |
| 300 | East | From Camera 1 | 61.47 | 56.29 | 66.47 |
| | North | From Camera 2 | | 56.29 | 68.21 |
| | | **Average** | | **56.29** | **69.10** |

### e. 2500-3

Test 2500-3 was completed without any incident. The variable stream nozzle was used on unit 520-06. The 90% control time was 37.34 seconds (Table 5), exceeding the criteria for success by 22 seconds. The time to full extinguishment was 56.75 seconds, or 63 seconds less than the 120 second maximum.

**Table 5. Extinguishment Times (seconds) and Parameters for Test 2500-3.**

| | | | Times (Seconds) | | |
|---|---|---|---|---|---|
| **Test Number** | **Camera View** | **Test Times Taken** | **Pre-Burn** | **90% Control** | **Full Extinguishment** |
| **2500-3** | | | 60.00 | | 58.78 |
| | | | | | 52.62 |
| | | | | | 63.00 |
| Fuel Load | | | | | 56.09 |
| 350 | East | From Camera 1 | 65.59 | 42.76 | 55.72 |
| | North | From Camera 2 | | 31.92 | 54.31 |
| | | **Average** | | **37.34** | **56.75** |

## 2. 3500 Sq. Ft. Fires

### a. 3500-1

640 gallons of fuel were poured and the fire was fought with unit 520-04 using the variable stream nozzle. Pre-burn lasted for 60 seconds to ensure pool area and F100 nacelle were involved. The firefighters were not able to extinguish the fire before running out of agent and evacuated the pit approximately three minutes after entering (Table 6).

**Table 6. Extinguishment Times (seconds) and Parameters for Test 3500-1.**

| | | | Times (Seconds) | |
|---|---|---|---|---|
| **Test Number** | **Camera View** | **Test Times Taken** | **Pre-Burn** | **Full Extinguishment** |
| **3500-1** | | | 60.00 | |
| | | | | |
| | | | | |
| Fuel Load | | | | |
| 640 | South | From Camera 1 | 62.58 | |
| | East | From Camera 2 | | |
| | | **Average** | | **DNE** |

**b. 3500-2**

Test 3500-2 was completed without any incident using unit 520-06. Firefighters were extinguishing spot fires when the agent was depleted. Two small fires, one on the rocks supporting the plane mock up and one between the two rings of the engine nacelle, continued to burn after the agent was exhausted. These small fires did not result in re-ignition of the remaining fuel on the pool surface, indicating a successful test. Full extinguishment time for the pool and F100 fire was 153.83 seconds (Table 7).

**Table 7. Extinguishment Times (seconds) and Parameters for Test 3500-2.**

| | | | Times (Seconds) | |
|---|---|---|---|---|
| **Test Number** | **Camera View** | **Test Times Taken** | **Pre-Burn** | **Full Extinguishment** |
| **3500-2** | | | 60.00 | 165.92 |
| | | | | 144.18 |
| | | | | 145.34 |
| Fuel Load | | | | 163.00 |
| 424 | South | From Camera 1 | 61.03 | 148.00 |
| | East | From Camera 2 | | 155.69 |
| | | **Average** | | **153.83** |

**c. 3500-3**

The final 3500-ft$^2$ pool fire was completed with the CAF nozzle on unit 250-04, by request of MARCORSYSCOM and AFRL, for a means of comparing system performance as a function of nozzle design. Full extinguishment time was 127.18 seconds, or 26 seconds faster than test 3500-2, which used the variable stream nozzle (Table 8). Examination of the unit after completion of the test showed foam and dry chemical agent remained, indicating that the unit capacity had not been fully exhausted.

**Table 8. Extinguishment Times (seconds) and Parameters for Test 3500-3.**

| | | | Times (Seconds) | |
|---|---|---|---|---|
| **Test Number** | **Camera View** | **Test Times Taken** | **Pre-Burn** | **Full Extinguishment** |
| **3500-3** | | | 60.00 | 127.83 |
| | | | | 118.66 |
| | | | | 137.94 |
| Fuel Load | | | | 121.78 |
| 500 | South | From Camera 1 | 60.87 | 135.81 |
| | East | From Camera 2 | | 121.06 |
| | | **Average** | | **127.18** |

### 3. 700 Sq. Ft. Fire

One 700-ft$^2$ fire was completed during this test series without any incident using the variable stream nozzle on unit 250-06. The TRIMAX 280 was able to control and extinguish the fire well within the capacity of the system at 22.77 and 32.36 seconds, respectively (Table 9).

**Table 9. Extinguishment Times (seconds) and Parameters for Test 700-1.**

| | | | Times (Seconds) | | |
|---|---|---|---|---|---|
| **Test Number** | **Camera View** | **Test Times Taken** | **Pre-Burn** | **90% Control** | **Full Extinguishment** |
| **700-1** | | | 45.00 | | 32.09 |
| | | | | | 33.60 |
| | | | | | 34.56 |
| Fuel Load | | | | | 30.53 |
| 65 | South | From Camera 1 | 45.81 | 23.83 | 32.85 |
| | East | From Camera 2 | | 21.70 | 30.53 |
| | | **Average** | | **22.77** | **32.36** |

## 4. Summary

Four of the five 2500-ft$^2$ fires (Figure 4) were controlled within the ARFF required time of 60 seconds, with the exception of test 2500-1, which had burn back from outside of the ring. Full extinguishment times ranged between 56.75-99.59 seconds, exceeding ARFF requirements by almost 20 seconds. Test 3500-1 with the variable nozzle was not extinguished. Tests 3500-2 using the variable nozzle showed full extinguishment at 153.83. Test 3500-3 using the CAFS nozzle showed full extinguishment at 127.18 seconds. The 700-ft$^2$ fire was quickly controlled and extinguished in less than 34 seconds.

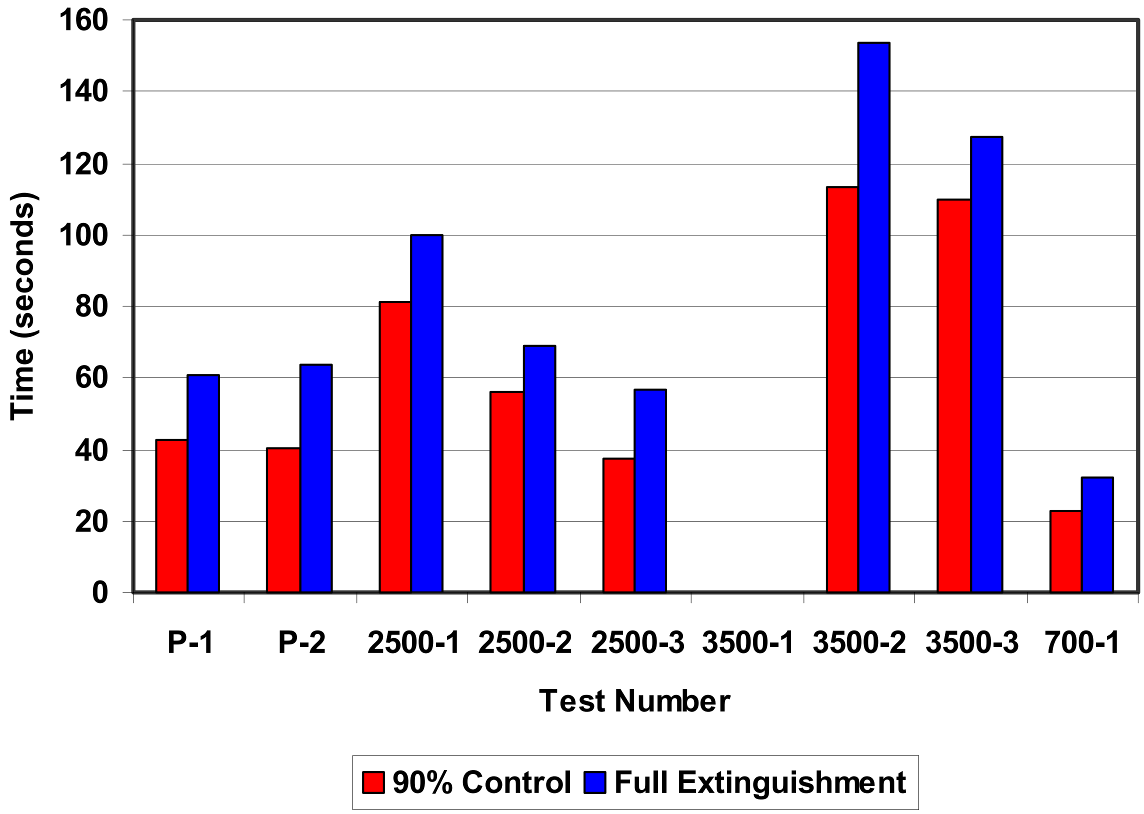


**Figure 4. Summary of Control and Extinguishment Times for all Fires.**

## B. *System Evaluation*

All system evaluations were completed with the variable stream nozzle, with the exception of the expansion ratio and drainage tests, which were completed with both nozzle types.

### 1. Maximum Throw Distance

Unit 520-06 showed a maximum throw range of 50 feet using foam only and 62 feet in dual agent mode (Table 10). This unit exceeded 50-foot minimum distance criteria when using either foam or foam in combination with dry chemical. Unit 520-04 produced a foam stream of 42 ft, or 8 ft shorter than unit 520-06. Changes in wind velocity and direction were attributed to this discrepancy. Unit 520-04 was not evaluated in dual agent mode, however, given the same increase in distance measured with unit 520-06, unit 520-04 would have exceeded the 50-foot minimum distance.

**Table 10. Throw Distances for Both Systems at Various Elevations and Wind Conditions.**

| Test | 520-04 Foam | 520-06 Foam | 520-06 Foam + PKP |
|---|---|---|---|
| **Throw Range** | | | |
| Level | 34’10” | | 35’7” |
| Max @ 20° | 42’ | 50’4” | 62’3” |

### 2. Agent Application Duration

During test 520-04, test personnel briefly (2-3 seconds) turned off the nozzle. The stopwatch was stopped and then restarted once the nozzle was turned back to the on position. The system showed a consistent foam application duration time exceeding 171 seconds and dry chemical application in excess of 71 seconds (Table 11).

**Table 11. Agent Application Duration in Minutes.**

| Test | 520-04 Foam | 520-04 PKP |
|---|---|---|
| Duration | 2:51:75 | 1:11:03 |

### 3. Agent Stream Decay over Application Time

Agent stream decay was an important system parameter to monitor. System operators need to know in advance if the throw distance changes as the agents were being depleted. Evaluation of the video from the TRIMAX 280 showed that the agent stream remained steady stream consistency and throw distance until the agents were almost depleted. This data showed that operators could expect 164 seconds of consistent agent application (Table 12). Only the foam agent in a straight stream pattern was evaluated for stream decay.

**Table 12. Time Elapsed Before Agent Stream Showed Decay.**

| Test Vehicle | Time (minutes) |
|---|---|
| 520-04 | 2:44.45 |

## 4. Agent Discharge Flow Rate

Video showed that the agent stream changed little over the course of discharge, which indicated a consistent flow rate. An inline flow meter was not installed for this test series for real time flow rate data, therefore, the flow rate was calculated as an overall average by dividing the volume of water in the tank by the time to discharge the full tank. The calculated flow rate for the foam was 27.9 gpm (Table 11). The dry chemical flow rate was calculated by dividing the capacity of the tank by the time to discharge the full tank. The calculated flow rate for the dry chemical was 2.82 pps (Table 13).

**Table 13. Flow Rate Measurements**

| Test Number | 520-04 Foam (gpm) | 520-04 PKP (pps) |
|---|---|---|
| Flow Rate | 27.907 | 2.8169 |

## 5. Foam Expansion Ratio and 25% Foam Drainage Time

A total of ten expansion ratio and two drainage tests were performed using the CAF and variable stream nozzle, with and without air injection.

### Foam Expansion Ratio

Foam expansion ratio tests conducted on the air-aspirated foam, with either the CAF nozzle or variable stream nozzle, showed that the system exceeded minimum requirements as stated in NFPA 412. NFPA minimum requirements for aspirated (or compressed air) AFFF are 5:1 expansion ratio (Table 12). System 520-04 produced foam with an expansion ratio of 8.61-8.80:1 with the CAF nozzle and 5.69-5.70:1 with the variable stream nozzle (Table 13). Four foam expansion ratio tests were conducted with the variable nozzle and no injection air (two tests with each system), which produced foam that was below the NFPA minimum expansion ratio requirements (2.39-2.62:1).

### 25% Foam Drainage Time

Similarly, the NFPA minimal requirement for 25% drainage time using test method A was 3 minutes (Table 14). The variable stream nozzle using injection air was the only configuration evaluated for drainage time for two reasons:

- The variable stream nozzle was identified as the preferred nozzle for Marine fire fighting applications to accompany the system.
- The variable stream nozzle, when used without injection air, did not meet NFPA minimum foam expansion ratio requirements.

System 520-04 produced foam with a 25% drainage time of 10.95-10.96 minutes using the variable stream nozzle in air-injection mode (Table 15), which exceeded NFPA minimum requirements.

**Table 14. NFPA Foam Quality Requirements.**

| | | Min Solution 25% Drainage Time in Minutes | |
|---|---|---|---|
| | Min Expansion Ratio | Test Method A | Test Method B |
| AFFF, Aspirated | 5:1 | 3 | 2.25 |
| AFFF, Non-aspirated | 3:1 | 1 | 0.75 |
| Protein | 8:1 | No data | 10 |
| Fluoroprotein | 6:1 | No data | 10 |

**Table 15. Results from Expansion Ratio and Drainage Testing for System 520-04.**

| Test No | Samples | Expansion Ratio | 25% Drainage |
|---|---|---|---|
| **1** | A - CAF nozzle, 50% air,520-04 | 8.80 | Na |
| | B - CAF nozzle, 50% air, 520-04 | 8.61 | Na |
| **2** | A - Variable nozzle, air off, 520-04 | 2.48 | Na |
| | B - Variable nozzle, air off, 520-04 | 2.62 | Na |
| **3** | A - CAF nozzle, 50% air, 520-06 | 7.46 | Na |
| | B - CAF nozzle, 50% air, 520-06 | 8.20 | Na |
| **4** | A - Variable nozzle, 50% air, 520-04 | 5.69 | 10.96 |
| | B - Variable nozzle, 50% air, 520-04 | 5.70 | 10.95 |
| **5** | A - Variable nozzle, air off, 520-06 | 2.57 | Na |
| | B - Variable nozzle, air off, 520-06 | 2.39 | Na |

# IV. Conclusions

## A. *Fire Scenarios*

### 1. 2500 Sq. Ft. Fires

The TRIMAX 280 exceeded the ARFF requirements for control (<60 seconds) and extinguishment (<120 seconds) of a 2500-$ft^2$ hydrocarbon pool fire. Four of the five fires reported control time less than 60 seconds. All five fires reported extinguishment times less than 120 seconds.

### 2. 3500 Sq. Ft. Fires

The TRIMAX 280 demonstrated acceptable fire control and extinguishment times of a 3500-$ft^2$ hydrocarbon pool fire with a F100 engine nacelle and aircraft mockup. Maximum control and extinguishment times were not established for this test. While the firefighters were not able to control and extinguish within the criteria established for the 2500 $ft^2$, the TRIMAX 280 was able to extinguish two of the three fires within the capacity of the system.

### 3. 700 Sq. Ft. Fire

The TRIMAX 280 test demonstrated quick fire control and extinguishment over a 700-$ft^2$ hydrocarbon pool fire with the F100 engine nacelle. While maximum control and extinguishment times were not established for this test, the TRIMAX 280 was able to fully extinguish the pool fire and F100 engine nacelle within 34 seconds.

## B. *System Evaluation*

### 1. Maximum Throw Distance

The system exceeded minimum requirements of a 50-foot throw distance in straight stream mode with the variable stream nozzle. The TRIMAX 280 has sufficient throw distance to provide adequate standoff distance for the firefighter, minimizing radiant heat exposure.

### 2. Agent Application Duration

The TRIMAX 280 has sufficient agent to provide foam application times just below three minutes and dry chemical application times in excess of one minute.

### 3. Foam Stream Decay over Application Time

The TRIMAX 280 provided consistent foam agent throw during 97.5% of the application duration. The agent stream did not decrease in throw range until less than three percent of the agent remained.

### 4. Agent Discharge Flow Rate

The manufacturer did not provide specification for the TRIMAX 280, therefore, comparison to NFPA 414 could not be conducted. Agent flow rate was adequate to control and extinguish all of the fire scenarios tested. Flow rate of the foam and dry chemical can be increased or decreased by adjusting the valves and pressure regulators on the system to customize flow rate for a particular operational setting.

### 5. Foam Expansion Ratio and 25% Drainage Time

The TRIMAX 280 exceeded minimum NFPA 412 requirements for foam expansion ratio when using the CAF nozzle or variable stream nozzle with injection air. The TRIMAX 280 did not meet minimum expansion ratio requirements when the variable stream nozzle was used without injection air (standard operating mode). Therefore, the variable stream nozzle must be used with 50% air injection in order to maintain the NFPA minimum foam quality requirements.

The TRIMAX 280 exceeded minimum NFPA 412 requirements for 25% drainage times when used with the variable stream nozzle in injection air mode (enhanced operating mode).

# V. References

1. Test Plan: TRIMAX 280. Marine Corps Systems Command. November 2001.
2. Test Plan: Evaluation of TRIMAX 280. Air Force Research Laboratory. November 2001.
3. NFPA 414: Standard for Aircraft Rescue and Fire-Fighting Vehicles. National Fire Protection Agency. 1995 Edition.
4. NFPA 412: Standard for Evaluating Aircraft Rescue and Fire-Fighting Foam Equipment. National Fire Protection Agency. 1998 Edition.

# Appendix

## *General Requirements for Expansion and Drainage Methods, Method A*

- The foam sample shall be collected in a standard 1000-ml capacity graduated cylinder. The cylinder shall be cut off at the 1000-ml mark to ensure a fixed volume of foam as a sample. The cylinder shall be marked in 10-ml graduations below the 100-ml mark. The container will be weighed dry to the nearest gram.
- The foam nozzle will be deflected off to the side of the foam collector until normal operating pressure and flow rate are achieved.
- The foam sample container will be completely filled with foam, the discharge nozzle will be shut off and the timing of the 25% drainage will begin.
- The foam container will be removed from the base of the foam collector and excess foam will be removed (from top and sides).
- The container will be placed on the balance and total weight of foam and container will be determined to the nearest gram. The weight of the foam will be determined from subtracting the weight of the empty container from the weight of the full container. The weight of the foam sample in grams will be divided by four to obtain the equivalent 25% drainage volume in milliliters.
- The foam sample will be placed on a level surface and the level of accumulation solution in the bottom of the cylinder will be noted and recorded every 30 seconds. The drainage will be recorded until 25% volume has been exceeded. The 25% drainage time will be interpolated from the data. Assume that 1 g of foam solution occupies approximately 1 ml.
- Expansion ration is as follows: Expansion = 1000 ml / (full weight) - (empty weight)
- Drainage Volume, 25% = volume of solution / 4

## List of Acronyms

Air Combat Element (ACE)

Air Force Research Laboratory (AFRL)

Compressed Air Foam (CAFS)

Combat Service Support Element (CSSE)

Commercial Utility Cargo Vehicle (CUCV)

Compressed Air Foam Mobile System (CAFS-M)

Gallons Per Minute (GPM)

High Mobility Multipurpose Wheeled Vehicle (HMMWV)

Key Performance Parameters (KPP)

Marine Air Ground Task Force (MAGTF)

Marine Corps System Command (MARCORSYSCOM)

National Fire Protection Agency (NFPA)

Operational Requirements Document (ORD)

Twin Agent Unit (TAU)